

HÆMODYNAMICS IN MITRAL STENOSIS BEFORE, DURING, AND AFTER VALVOTOMY*

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The effectiveness of mitral valvotomy at the time of operation is usually judged by the surgeon's estimate of the amount of split of the fused commissures. In experienced hands, this is fairly reliable and barring complications the results are usually satisfactory if a good split has been obtained. However, the need for reliable objective assessment has always been felt and if a method could be found whereby the ultimate result of the surgical procedure could be foretold at the time of operation, the surgeons would be considerably helped.

MATERIAL AND METHOD

In 32 cases of mitral stenosis, pressure studies were made during the operation. These included recording of pressures in the pulmonary trunk, left atrium, and left ventricle, both before and after valvotomy (Table I). Mean values were obtained by planimetric integration of the pressure

TABLE I
PRESSURE STUDIES MADE BEFORE, DURING, AND AFTER MITRAL VALVOTOMY

Case No.	Mean P.A. in mm. Hg		Mean L.A. in mm. Hg		L.V. (S/D) in mm. Hg		Surgeon's estimate M.V. diameter in cm.		L.V. diastolic filling pressure gradient mm. Hg	
	Before	After	Before	After	Before	After	Before	After	Before	After
6	49	40	34	20	95/23	95/12	0.75	3.00	5	1
9	—	—	23	—	75/4	—	1.00	3.00	4	—
11	34	31	18	15	105/7	104/8	1.50	3.50	8	5
12	70	67	41	21	90/7	97/15	1.00	3.00	16	2
13	38	23	15	10	78/10	84/10	0.70	—	9	0
15	34	23	18	14	94/10	87/4	1.25	2.50	4	4
18	32	32	19	14	75/7	72/4	Unsatisfactory split		7	6
21	31	26	17	12	96/8	118/5	1.50	3.00	5	2
23	27	25	15	9	88/7	75/3	1.00	3.00	6	2
25	24	18	12	6	110/0	100/5	0.75	3.50	4	0
26	25	16	17	13	70/7	90/7	1.00	4.00	5	2
27	80	49	43	32	90/28	100/25	1.00	3.50	4	1
29	27	25	20	18	97/12	110/18	1.50	4.00	6	0
30	46	27	42	13	90/12	85/10	1.00	4.00	17	0
31	80	29	47	29	90/0	75/0	0.50	3.00	20	1
34	38	31	24	21	80/8	98/12	1.00	3.50	6	2

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tracings. The left ventricular filling pressure gradient was determined from the pressure curves obtained before and after operation and also by planimetric integration, after interpolation of the left atrial pressure tracings over the left ventricular curves (Fig. 1). Simultaneously, the surgeon's estimate of the grade of split in cm. as judged by his finger was also recorded.

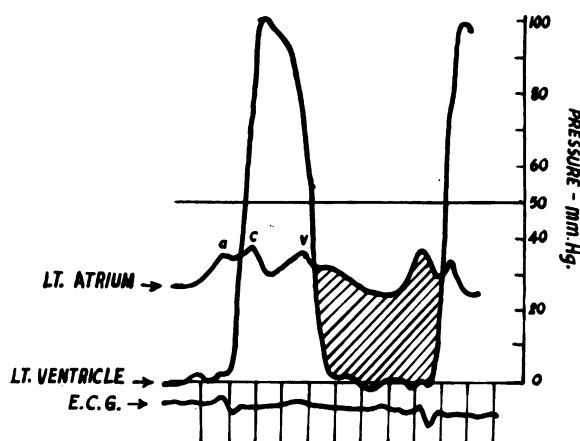


FIG. 1.—Showing the left atrial pressure tracing super-imposed on the left ventricular pressure curve. The shaded area represents the left ventricular filling pressure gradient.

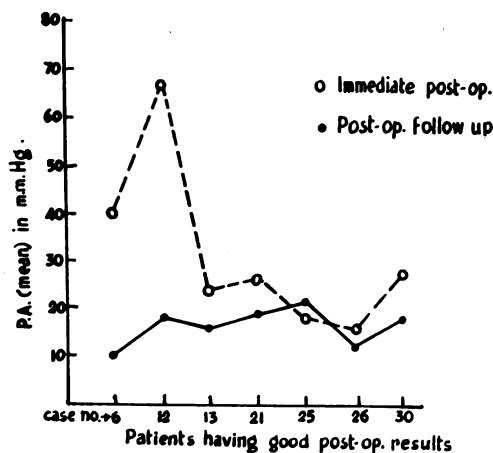


FIG. 2.—Showing the relation between the pulmonary arterial pressure immediately after valvotomy and in the post-operative follow up in those patients in whom the result was "good."

Of these 32 patients, 16 had pre- and post-operative right heart catheterization. These studies were conducted under identical basal conditions. The later catheterization was performed between 7 to 12 months after operation. The data obtained from these procedures included amongst others (Table II) the following.

(1) *The cardiac index (C.I.)*—obtained by dividing the cardiac output in litres a minute by the body surface area in square metres.

The cardiac output was measured from the Fick's principle

$$\text{Cardiac output/l./min.} = \frac{\text{O}_2 \text{ consumption in c.c./min.}}{(\text{arterio-venous oxygen difference in vol. \%}) \times 10}$$

(2) *Mean pressures in (a) pulmonary artery (P.A.); (b) pulmonary capillary wedge pressure (P.C.)*

(3) *Pulmonary vascular resistance (P.V.R.) in units.* This was determined by dividing the difference of mean pulmonary arterial pressure and the mean pulmonary capillary pressure by the cardiac output in litres per minute.

$$\text{PVR in units} = \frac{\text{PA(mean)} - \text{PC(mean)}}{\text{C.O. l./min.}}$$

(4) *Mitral diastolic filling period (M.D.F.P.)—sec./min.* This was obtained by multiplying the left ventricular filling period during each cardiac cycle by the heart rate per minute. The period of diastole per beat was measured from the brachial arterial tracing. This consisted of the duration from the beginning of the dicrotic notch to the beginning of the upstroke of the next arterial pulse.

It was shown by Gorlin (1951) that the diastolic filling period measured in this manner was not significantly different from the actual left ventricular filling period.

TABLE II
DATA FROM PRE- AND POST-OPERATIVE CATHETERIZATION STUDIES

Case No. (Result)	Time of study	Follow up after op. in months	Disability grade	Cardiac rhythm	Cardiac index in l./min./sq. m.	PA (mean) in mm. Hg	PC (mean) in mm. Hg	PVR in units	Mitral diastolic filling period sec./min.	Mitral valve flow in ml./sec.	Mitral valve area in sq. cm.
6 (Good)	Pre-op.	—	3	S.R.	2.2	38	27	3.6	33.7	89	0.78
	Post-op.	8	0	S.R.	2.9	10	3	1.8	29.4	132	—
9 (Sl. Imp.)	Pre-op.	—	3	S.R.	2.7	50	22	8.0	26.0	142	1.10
	Post-op.	8	2	A.F.	3.4	18	8	2.4	33.0	124	1.26
11 (Poor)	Pre-op.	—	2	S.R.	—	34	17	—	—	—	—
	Post-op.	8	2	S.R.	2.8	37	19	5.0	32.7	110	0.95
12 (Good)	Pre-op.	—	3	S.R.	2.1	40	21	7.9	36.5	66	0.53
	Post-op.	9	0	S.R.	4.3	18	11	1.4	22.0	227	3.00
13 (Good)	Pre-op.	—	3	A.F.	2.0	47	22	7.8	28.7	111	0.87
	Post-op.	10	0	A.F.	2.5	16	7	2.2	21.1	189	4.30
15 (Fair)	Pre-op.	—	2	S.R.	2.8	35	24	2.7	22.4	178	1.30
	Post-op.	8	1	S.R.	2.9	44	25	4.5	27.0	155	1.16
18 (Poor)	Pre-op.	—	3	S.R.	2.0	48	27	7.7	38.2	70	0.48
	Post-op.	9	3	A.F.	2.5	51	30	6.0	37.4	88	0.56
21 (Good)	Pre-op.	—	2	S.R.	2.1	35	18	5.1	34.3	96	0.86
	Post-op.	8	0	S.R.	3.7	19	14	0.9	23.6	250	2.80
23 (Sl. Imp.)	Pre-op.	—	4	A.F.	2.5	22	14	2.2	40.7	88	0.94
	Post-op.	7	3	A.F.	2.7	36	23	3.4	40.1	94	0.72
25 (Good)	Pre-op.	—	2	S.R.	3.2	29	15	3.2	33.5	128	1.30
	Post-op.	7	0	S.R.	2.6	21	11	2.7	21.0	214	2.80
26 (Good)	Pre-op.	—	2	S.R.	2.1	20	17	0.83	27.0	133	1.23
	Post-op.	7	0	S.R.	3.0	12	9	0.54	36.1	152	2.40
27 (Sl. Imp.)	Pre-op.	—	4	A.F.	1.2	44	26	9.2	28.20	58	0.41
	Post-op.	7	3	A.F.	2.2	26	15	3.9	18.66	150	1.50
29 (Fair)	Pre-op.	—	2	S.R.	2.4	16	13	1.2	27.1	140	1.50
	Post-op.	7	1	S.R.	2.5	18	12	1.4	28.1	143	1.70
30 (Good)	Pre-op.	—	2	S.R.	2.5	50	37	3.9	33.7	98	0.55
	Post-op.	7	0	S.R.	3.1	18	10	1.5	26.58	194	2.80
31 (Sl. Imp.)	Pre-op.	—	4	S.R.	1.5	56	23	17.3	33.8	56	0.42
	Post-op.	9	2	S.R.	3.0	36	16	4.8	31.0	132	1.23
34 (Fair)	Pre-op.	—	3	S.R.	3.1	51	23	8.0	29.90	117	0.89
	Post-op.	6	1	S.R.	4.0	28	16	2.4	33.28	150	1.46

(5) *Mitral valve flow (M.V.F.) ml./sec.* was estimated by dividing the cardiac output in ml. per minute by the duration in seconds of the mitral diastolic filling period per minute.

(6) *Mitral valve area (M.V.A.) in sq. cm.* was calculated with help of Gorlin's formula.

$$M.V.A. = \frac{M.V.F.}{31 \times \sqrt{(P.C. - 5)}}$$

where M.V.F. = Mitral valve flow in ml./sec.

P.C. = Mean pulmonary capillary pressure in mm. Hg.

5 = Assumed left ventricular diastolic mean pressure in mm. Hg.

31 = Constant factor estimated for mitral valve (Gorlin, 1951).

The factor (PC-5) was considered to be approximately equal to the pressure gradient across the mitral valve by Gorlin. It was claimed that as the square root of the factor was used in the area equation, a slight deviation from the actual pressure gradient would not materially alter the value of the mitral valve area.

The clinical state of the patients had been followed up and their disability grades were assessed before and after operation according to the criteria of Wood (1954) and Goodwin *et al.* (1955).

Grade I. Dyspnoea on exertions like running, heavy manual labour, or playing strenuous games, but not interfering with ordinary activities.

Grade II. Dyspnoea on moderate exertions like walking at average pace, climbing stairs, etc.; ordinary household activities performed without much difficulty.

Grade III. Dyspnoea experienced on slight exertion such as walking slowly, the patient being handicapped.

Grade IV. Dyspnoea on slight exertion; severe effort intolerance sometimes with confinement to bed.

The results of the operations were considered as "good" when the disability grade had been abolished or reduced by at least three grades, and "fair" when the disability had been reduced to grade 1 or had been lowered by at least two grades. "Slight improvement" indicated that the disability had decreased by one grade but not to grade 1, while "poor" meant that the disability had remained unchanged or had worsened.

The pressures obtained during operation were compared with those obtained at pre- and post-operative catheterization. The fall in the left ventricular diastolic filling pressure gradient at the time of operation, in conjunction with simultaneously recorded left ventricular and left atrial pressures, was correlated with the eventual hæmodynamic state of the patient and his clinical improvement.

RESULTS

On the basis of their eventual grade of disability and the resultant clinical state, seven patients (Cases 6, 12, 13, 21, 25, 26, and 30) were considered as having had good results. Four (Cases 9, 15, 29, and 34) had fair results. Three (Cases 23, 27, and 31) had slight improvement, and two (Cases 11 and 18) had poor results. The reduction in the diastolic pressure gradient, the surgeon's estimate of the split, development of mitral regurgitation if any and its intensity, the presence or absence of atrial fibrillation, and the occurrence of any other complication are illustrated in Table III.

TABLE III
VARIOUS FACTORS INFLUENCING THE RESULT OF MITRAL VALVOTOMY

Case No.	Post operative result	Mitral diastolic filling pressure gradient in mm. Hg		Surgeon's estimate of M.V. diameter in cm.		Mitral valve regurgitation		Atrial fibrillation		Other complications
		Before split	After split	Before split	After split	Before split	After split	Before split	After split	
6	Good	5	1	0.75	3.0	—	—	—	—	—
9	Sl. imp.	4	—	1.0	3.0	+	++	—	+	—
11	Poor	8	5	1.5	3.5	—	—	—	—	—
12	Good	16	2	1.0	3.0	—	+	—	—	—
13	Good	9	0	0.7	—	+	+	+	+	—
15	Fair	4	4	1.25	2.5	++	+++	—	—	—
18	Poor	7	6	Unsatisfactory split	—	—	—	—	+	—
21	Good	5	2	1.5	3.0	—	+	—	—	—
23	Sl. imp.	6	2	1.0	3.0	—	+++	+	+	—
15	Good	4	0	0.75	3.5	—	+	—	—	—
26	Good	5	2	1.0	4.0	—	—	—	—	—
27	Sl. imp.	4	1	1.0	3.5	—	—	+	+	Myocardial insufficiency
29	Fair	6	0	1.5	4.0	—	—	—	—	—
30	Good	17	0	1.0	4.0	—	—	—	—	—
31	Sl. imp.	20	1	0.5	3.0	++	++	—	—	Chronic & marked eosinophilia
34	Fair	6	2	1.0	3.5	—	—	—	—	—

The relationship between pre-operative, operative (pre- and post-valvotomy) and post-operative pulmonary arterial pressure studies and the associated fall in the pulmonary vascular resistance are shown in Table IV. In seven, instances the pulmonary arterial pressure recorded at operation was less than the pre-operative level. In nine it was increased and in three much increased. In general, there was little correlation between these two pressure studies. When the immediate post-valvotomy pulmonary arterial pressure is compared to the eventual pressure recorded 7 to 12 months after operation, the difference is striking (Fig. 2). In general, there was also close

TABLE IV

RELATIONSHIP BETWEEN PULMONARY ARTERIAL PRESSURES AND THE ULTIMATE FALL OF PULMONARY VASCULAR RESISTANCE AFTER OPERATION

Case No.	Mean pulmonary arterial pressure in mm. Hg				Pulmonary vascular resistance in units	
	Pre-operative	Operative		Post-operative	Pre-operative	Post-operative
		Before split	After split			
6	38	49	40	10	3.6	1.8
9	50	—	—	18	8.8	2.4
11	34	34	31	37	—	5.0
12	40	70	67	18	7.9	1.4
13	47	38	23	16	7.8	2.2
15	35	34	23	44	2.7	4.5
18	48	32	32	51	7.7	6.0
21	35	31	26	19	5.1	0.9
23	22	27	25	36	2.2	3.4
25	29	24	18	21	3.2	2.7
26	20	25	16	12	0.8	0.5
27	44	80	49	26	9.2	3.9
29	16	27	25	18	1.2	1.4
30	50	46	27	18	3.9	1.5
31	56	80	29	36	17.3	4.8
34	51	38	31	28	8.0	2.4

correlation between the post-operative fall of the pulmonary arterial pressure and the reduction of the pulmonary vascular resistance. In those patients in whom the pulmonary arterial pressure did not fall significantly or remained steady or increased, the P.V.R. also showed concomitant increase (Case 15, 18, 23, 25, and 29).

The fall in the diastolic pressure gradient measured at operation closely corresponded to the eventual fall in the pulmonary arterial pressure and the reduction in the pulmonary vascular resistance (Table V). When the gradient did not fall properly (Cases 15, 18), there was either no reduction or increase in the eventual pulmonary arterial pressure or the pulmonary vascular

TABLE V

RELATIONSHIP BETWEEN FALL IN MITRAL DIASTOLIC FILLING PRESSURE GRADIENT, EVENTUAL FALL IN PULMONARY ARTERIAL PRESSURE, AND REDUCTION OF PULMONARY VASCULAR RESISTANCE

Case No.	Mitral diastolic filling pressure gradient in mm. Hg		Mean pulmonary arterial pressure in mm. Hg		Pulmonary vascular resistance in units	
	Before split	After split	Pre-operative	Post-operative	Pre-operative	Post-operative
6	5	1	38	10	3.6	1.8
9	4	—	50	18	8.0	2.4
11	8	5	34	37	—	5.0
12	16	2	40	18	7.9	1.4
13	9	0	47	16	7.8	2.2
15	4	4	35	44	2.7	4.5
18	7	6	48	51	7.7	6.0
21	5	2	35	19	5.1	0.9
23	6	2	22	36	2.2	3.4
25	4	0	29	21	3.2	2.7
26	5	2	20	12	0.8	0.5
27	4	1	44	26	9.2	3.9
29	6	0	16	18	1.2	1.4
30	17	0	50	18	3.9	1.5
31	20	1	56	36	17.3	4.8
34	6	2	51	28	8.0	2.4

resistance. There was one exception (Case 23) in which the pulmonary arterial pressure and the resistance increased in spite of satisfactory fall in gradient.

When the pre- and post-operative capillary wedge pressures are compared with operative (pre- and post-valvotomy) left atrial pressure and the latter is correlated with the change in the gradient brought about as the result of valvotomy, (Table VI) the relationship appears to be somewhat different from a similar pulmonary arterial pressure study. The pre-operative capillary wedge pressure has no definite relationship to the pre-operative left atrial pressure taken at the time of operation. The immediate fall in the left atrial pressure following satisfactory valvotomy is greater than the resultant fall in pulmonary arterial pressure. When ventricular diastolic pressure rose following valvotomy (as happened in some cases) this fall was not significant. The eventual post-operative pulmonary capillary wedge pressure was also closely related to the reduction in the diastolic pressure gradient as measured at operation. When reduction in gradient was satisfactory, the eventual capillary wedge pressure was substantially reduced; when the gradient was not diminished (Case 15 and 18), the wedge pressure increased. Again, the exception was in Case 23 in whom, in spite of a fall in gradient, the wedge pressure increased from 14 to 23 mm. Hg. A likely explanation of this seeming anomaly will be discussed later.

TABLE VI

RELATIONSHIP BETWEEN PULMONARY CAPILLARY WEDGE PRESSURE AND MITRAL VALVE DIASTOLIC FILLING PRESSURE GRADIENT IMMEDIATELY BEFORE AND AFTER MITRAL VALVOTOMY

Case No.	Mean pulmonary capillary wedge pressure in mm. Hg		Mean left atrial pressure in mm. Hg		Mitral valve diastolic filling pressure gradient in mm. Hg	
	Pre-operative	Post-operative	Before split	After split	Before split	After split
6.	27	3	34	20	5	1
9.	22	8	23	—	4	—
11.	17	19	18	15	8	5
12.	21	11	41	21	16	2
13.	22	7	15	10	9	0
15.	24	25	18	14	4	4
18.	27	30	19	14	7	6
21.	18	14	17	12	5	2
23.	14	23	15	9	6	2
25.	15	11	12	6	4	0
26.	17	9	17	13	5	2
27.	26	15	43	32	4	1
29.	13	12	20	18	6	0
30.	37	10	42	13	17	0
31.	23	16	47	29	20	1
34.	23	16	24	21	6	2

The left ventricular pressures were determined before and after valvotomy. Eight patients showed some increase in pressure following it, while four showed a slight fall, and four slight or no change.

DISCUSSION

It is well known that the demonstration of a pressure gradient across the mitral valve, between the left atrium and the left ventricle, gives the best possible indication of existence of mitral stenosis. However, to know accurately the severity of the stenosis and the functional size of the mitral orifice, the flow across the valve and the cardiac output must be measured at the same time (Dickens *et al.*, 1959). Determination of flow rates by dye dilution technique at the time of operation is time consuming and necessitates the use of complicated equipments which are beyond the reach of most surgical centres. In this study, an attempt has been made to correlate the fall in left

ventricular diastolic pressure gradient across the mitral valve in conjunction with simultaneously recorded left ventricular and left atrial pressure measurements, with the eventual benefit to the patient as judged by detailed hæmodynamic studies 7 to 12 months after operation. This latter study included determination of the cardiac output and cardiac index, mitral diastolic filling period, mitral valve flow rate, and mitral valve area. An opportunity was thus afforded of judging critically the value and usefulness of the gradient determination at the time of operation in forecasting the ultimate result of the operation.

There are various ways in which the diastolic pressure gradient can be determined. Some employ the end diastolic pressure gradient, i.e. the gradient at the end of diastole, but it is well known that measurement of pressure at any single instant during diastole gives an inadequate picture of the pressure difference during ventricular filling. Fox *et al.* (1956) advocated recording the gradient at three phases of the diastolic period (Fig. 3). However planimetric integration of the gradient during each instant of the diastole gives a more accurate idea of the overall gradient and this method was employed in the present study.

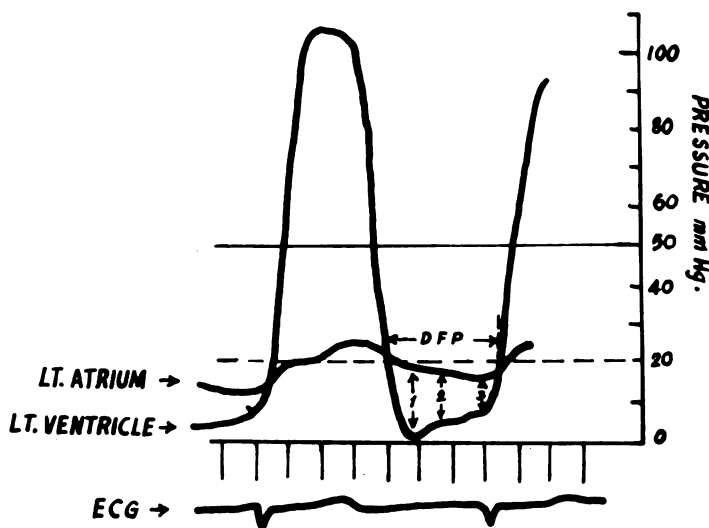


FIG. 3.—Shows the left ventricular filling pressure gradient at three phases of the diastolic cycle.

The diastolic pressure gradient may fall in two ways. The left atrial pressure may be reduced and approximate to the low ventricular diastolic pressure (Fig. 4) or the latter may be raised. In the latter case, the left atrial pressure will remain raised (Fig. 5) although the gradient will be reduced.

It will be seen that of the seven patients who were classified as having had good results (Cases 6, 12, 13, 21, 25, 26, and 30), all had satisfactory reduction of the gradient at the time of operation following valvotomy and the resultant gradient was less than 2 mm. Hg. In the post-operative hæmodynamic study also, these patients had satisfactory reduction of their P.V.R. (maximum reduction being 13 units in Case 30), the mitral valve flow increased considerably (maximum increase from 96 to 250 ml. per sec. in Case 21) and there was considerable increase in functioning mitral valve area (maximum increase from 0.8 to 4.3 sq. cm. in Case 13). The pulmonary capillary wedge pressure had also fallen significantly (maximum from 27 to 3 mm. Hg in Case 6). In all of these seven cases, the surgeon's estimate of the split of the commissures was satisfactory and the mitral orifice exceeded 3 or 3.5 cm. in diameter. If there was regurgitation after the operation it was of minor grade.

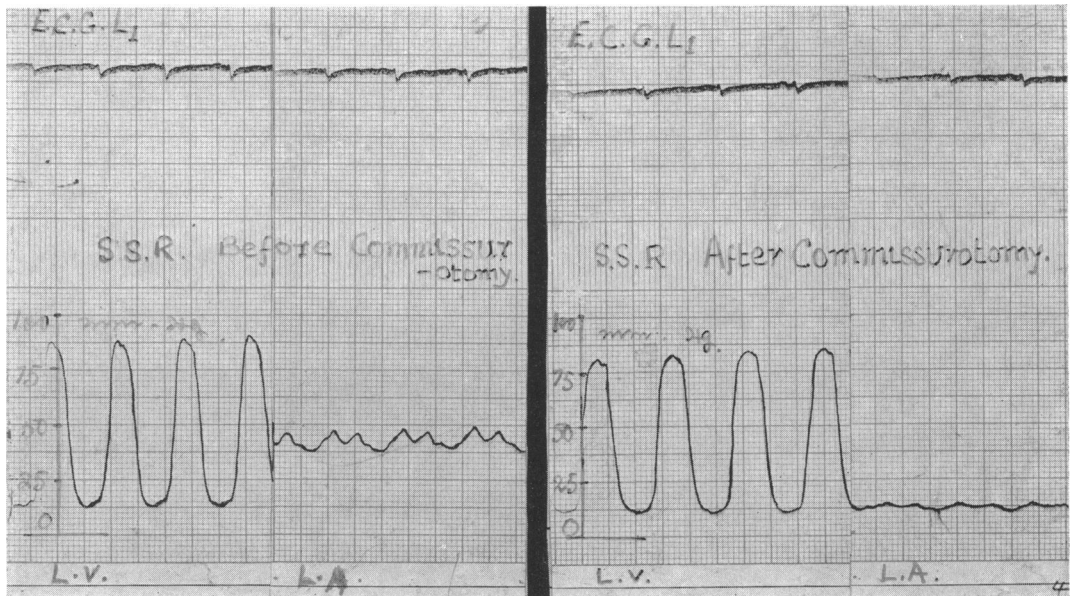


FIG. 4.—Shows the fall of the left ventricular diastolic pressure gradient due to reduction of the left atrial pressure.

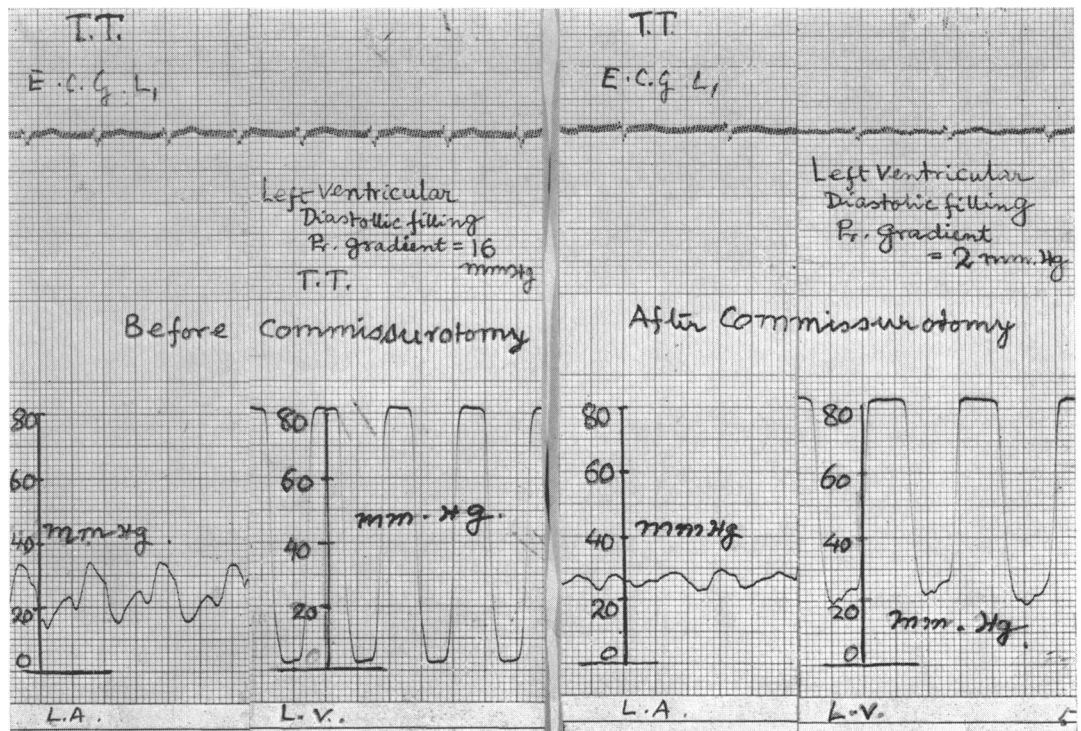


FIG. 5.—Shows the reduction of the left ventricular filling pressure gradient due to elevation of the ventricular diastolic pressure.

Amongst the three patients who were considered to have had fair results (Cases 15, 29, and 34), two had satisfactory reduction of gradient at the time of operation (Cases 29 and 34) and the split was adequate (4 cm. and 3.5 cm.). Similarly, their P.V.R. was well reduced while the mitral valve flow and area increased considerably. They were classed only fair because their grade of disability had come down to I instead of 0 and had been reduced by two grades instead of three. In the third case (Case 15), the split was inadequate (2.5 cm.), the gradient was not reduced; the P.V.R. had increased after operation and there had been little improvement in mitral valve flow and area. The patient had developed fibrillation and yet he felt better while the disability grade had improved from II to I. Psychological influences of the expected benefit from the operation can not be ruled out in this case and the seeming improvement may not last for long.

The patients who were classed as having had slight improvement (Cases 9, 23, 27, and 31) are interesting. In all four the split had been satisfactory, the resultant orifice exceeding 3 cm. in diameter, while the gradient had also been reduced considerably, in one (Case 31) from 20 to 1 mm. Hg; and yet in each the clinical state and the disability grade were unsatisfactory. In the post-operative hæmodynamic study, the P.V.R., and the mitral valve flow and area had not improved adequately, or had even deteriorated. Causes of failure in these instances were as follows: three of the patients had developed a significant degree of mitral regurgitation, three were fibrillating, one had considerable pulmonary eosinophilia (Case 31), and one had irreversible myocardial insufficiency (Case 27) as judged by the large size of the heart and evidence of chronic right heart failure. Case 23 had both atrial fibrillation and mitral regurgitation. Thus, although the gradient may be reduced well by a good split, complications such as the foregoing may vitiate the ultimate result.

In the two patients (Cases 11 and 18) who had poor results, the split was unsatisfactory as judged by the surgeon, the gradient had not fallen below 5 mm. Hg, and the ultimate hæmodynamic data did not show improvement as compared with the pre-operative findings.

Gradient determination at the time of operation, in conjunction with the recording of the resultant left ventricular and left atrial pressures, is a worthwhile procedure to assess the likely result of the operation and may give some objective information in addition to what is obtained digitally in the atrium by the surgeon. If the mitral valve flow could be measured simultaneously, this would make the study even more complete. Some idea of the change in the flow rate can be obtained by the resultant left ventricular pressure following operation. Increase of mitral valve flow is likely to be associated with some rise in the left ventricular pressure or the pressure may remain unchanged if the ventricular myocardium can immediately accommodate the increased volume. Therefore, if the mean diastolic pressure gradient across the mitral valve shows satisfactory diminution following valvotomy and if concomitantly the left ventricular pressure does not fall significantly or remains unchanged or shows some rise, the ultimate result is likely to be good. In fact, it seems to us that with a good split and with no complications arising, the gradient will always fall even if the flow is increased. The only other way by which the gradient could fall would be by reduction of flow due to myocardial failure and this will be immediately evident by sharp reduction of the intra-ventricular pressure.

Conversely, if the gradient has not fallen satisfactorily following operation, the split is not likely to have been adequate and the ultimate result will not be good. Increase of flow after inadequate split is likely to result in further augmentation of the gradient. In this series, it was seen that the gradient after valvotomy should diminish to 2 mm. Hg or lower for the best possible result to be obtained.

It may well be asked how determination of the pre- and post-operative pressure gradient is an advantage over the surgeon's estimate of the split at the time of operation. It is well known that surgeons are liable to overestimate their correction of the stenosed valve. To be over enthusiastic about one's own handiwork is a natural human frailty over which it is difficult to take issue.

It has been shown that if careful pre- and post-operative gradient determinations are made, better objective evaluation of the result will be immediately available. It must be emphasized, that the gradient falls greatly if the split exceeds 3 or 3.5 cm., as shown in this series. This degree

of splitting may be considered adequate under the conditions that exist when the patient is under the anæsthetic. With increasing experience of the operation, most surgeons have felt that even more extensive splitting is necessary for long-term improvement. The operative gradient reduction should therefore be accepted with this probability in mind.

The relation of the gradient fall to the pre- and post-operative pulmonary arterial pressure and the relation of the latter to the eventual fall in pulmonary arterial pressure has already been stressed. It was remarkable that, provided the gradient was reduced and no complications ensued, the pulmonary arterial pressure fell significantly and reached almost normal proportions in the long-term follow up, even though immediately after the operation it showed an insignificant fall.

The left atrial pressure study was seen to reflect more closely the gradient fall before and after valvotomy: it fell substantially in almost every case with the exception of those in which the ventricular diastolic pressure rose.

SUMMARY

In 32 patients with mitral stenosis, observations were made of the pressures in the pulmonary artery, left atrium, and left ventricle before and after valvotomy; the reduction of the ventricular diastolic filling pressure gradient following the operation was also determined. Of these cases 16 had detailed hæmodynamic studies by right heart catheterization before and about 7–12 months after operation. This observation included determination of pulmonary vascular resistance, mitral valve flow, and mitral valve area. The pressures at operation, and particularly the gradient fall, were correlated with the pre- and post-operative catheterization findings and also with the eventual clinical state and the disability grades of the patients.

It was found that when the fall in gradient had been satisfactory (preferably to below 2 mm. Hg), the eventual clinical and hæmodynamic state of the patient was good, provided that the left ventricular pressure had not fallen significantly and provided complications such as mitral regurgitation, atrial fibrillation, and chronic myocardial failure had not occurred. The gradient fall may thus supplement the surgeon's estimate of the split in assessing the benefit likely to result from the operation.

The pulmonary arterial pressure does not always fall to any extent immediately following valvotomy even when the split is adequate, but whenever, the gradient is well reduced, there is a progressive fall of this pressure over the course of months and the final pressure may almost reach normal.

The left atrial pressure follows more closely the reduction in the gradient and falls concurrently following satisfactory split of the commissures. An exception must be made of those patients in whom the ventricular diastolic pressure shows some rise after valvotomy; then the left atrial pressure also remains raised although the gradient is reduced.

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